Safety Analysis Report 306-W Building

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January 1979

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by Battelle Memorial Institute

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Richland, Washington 99352

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SAFETY ANALYSIS REPORT

306-W BUILDING

INTRODUCTION

This report presents a safety analysis of the work performed and of the equipment in the 306-W Building to assure that credible accidents will not constitute an undue risk to employees or the public. This assurance is provided by determining that a postulated accident is either incredible by the nature of the work or by the facility's engineered safety features or that credible accidents do not represent an undue environmental risk. The analyses cover criticality and radiological accidents as well as industrial accidents that could contribute to a criticality or radiological accident. The types of accidents considered include those caused by natural forces and failure of process, equipment, engineered safety features and procedures.

Accidents were selected by a review of all the operations being performed in the building and of the facility's installed equipment and engineered safety features. Safety data from similar nuclear operations and past experience were used in the review. The prime objective of the review and analyses was to assure that no accident will occur in the building that would have consequences more severe than the accidents covered by this report.

1. SUMMARY

The west portion of the 306 Building (designated as 306-W) is operated by Pacific Northwest Laboratory of the Battelle Memorial Institute under a contract with the Department of Energy (DoE).

The east portion of the building (designated as 306-E) is operated by Hanford Engineering Development Laboratory, Westinghouse Hanford Company.

The Battelle-Northwest occupied portion of the 306 Building contains 1) a diversified metalworking facility, 2) the BNW Specialty Shop that provides machining services for uranium, thorium, and other materials of low specific radioactivity, 3) a Ceramics Laboratory, 4) SNM Storage Area and 5) Support Laboratories.

Complete isolation of the HEDL portion from the BNW portion of the building is provided by metal or concrete block partitions with a 1-1/2 hour UL fire rating. All doorways through this partition are locked for security reasons. Although the HEDL portion of the building may at any time contain enriched uranium in the form of billets, fuel elements, and scrap, this SAR does not cover the activities of the HEDL section of the building, except that the potential presence of such materials is considered in the establishment of administrative controls pertaining to the handling of fissile materials within the Battelle-Northwest portion of the building.

The activities and administrative controls associated with the BNW facilities are presented in four separate sections of this report. Also included in each section is a safety analysis for that section. Section 6.1 covers the activities and controls associated with the diversified metalworking facility. Section 6.2 covers the activities and controls associated with the Ceramics Laboratory. Section 6.3 covers the activities and controls associated with the Specialty Shop. The last section (6.4) covers the operations

and activities associated with the SNM Storage Area. Overall responsibility for BNW's portion of the 306 Building lies with the Materials Department Building Manager.

2. SITE DESCRIPTION

This section primarily describes those features of the site which are relevant to the safe operation of the 306-W Building. Because there is only a very small offsite release of radioactivity from the most serious postulated accident, all features are described only briefly. A more complete description of these features may be found in "300 Area Site Description."⁽¹⁾

2.1 Location

The 306-W Building is located near the northeast corner of the 300 Area (Figure 1) of the DOE Hanford Reservation. The 300 Area is a section of about 400 acres in the southeast corner of the reservation, on the west bank of the Columbia River, about seven miles north of the city center of Richland, Washington.

2.2 Wind

The Pacific Northwest is one of the areas of the country with the lowest frequency of tornadoes. On the average the state of Washington experiences less than one tornado each year. Fourteen tornadoes have been recorded within a 100-mile radius of the Hanford area since 1916. These were of relatively short duration, reaching ground level for brief periods and causing only slight damage. One small tornado (June 16, 1948) and two funnel clouds have been observed in 29 years (1945-1973) at Hanford. These were sighted along Rattlesnake Mountain, about 15 miles west of the 300 Area.

Peak wind gusts of 60 mph or more are expected on the average of once every two years. Windstorms can occur during any time of the year, as each month has experienced a peak wind gust of 55 mph or greater at least once during the period 1945-1973. The all-time record peak wind recorded at the 50-foot level of the Hanford Meteorological Station tower was a gust of 80 mph January 11, 1972. Based on a study described in the "300-Area Site Description,"⁽¹⁾ a gust of 86 mph is expected to occur about once every 100 years.

Several studies have been made of the maximum wind speed and the probability of a tornado striking a specific location.⁽¹⁾ These studies conclude that the probability of a tornado hitting a particular facility on site is six chances in a million during any given year or about one chance in 4000 during a 40-year plant life.

2.3 Seismology

Eastern Washington is a region of low to moderate seismicity that lies between the more active seismic zones of western Washington and western Montana. Based on seismic history since 1840, the US Coast and Geodetic Survey has designated eastern Washington as Zone 2 seismic probability, implying a potential for moderate damage from earthquake.

The strongest earthquakes recorded on the Hanford Reservation within historic times have been a factor of 10 below the seismic probability of Zone 2.

The lack of well-defined earthquake zones and the observance of no earthquake exceeding MM-IV on the Hanford reservation corroborate the opinion that Hanford is in a region of moderate to minor seismicity, implying that the facility design based on a probable maximum earthquake intensity of MM-VII is conservative and consistent with good design practice.

2.4 Miscellaneous Features

2.4.1 Flooding

The normal level of the Columbia River at the 300 Area is 340 feet above mean-sea level. This level normally fluctuates from a low of about 335 feet to a high during spring runoff of about 350 feet. The probable maximum flood of the Columbia River projected by the US Army Corps of Engineers produces a river elevation at the 300 Area of 382 ± 4 feet above mean-sea level. The ground floor of the 306-W Building is ten feet above this probable maximum flood level.

2.4.2 Precipitation

The Hanford Area receives a yearly total precipitation averaging 6.25 inches, of which about 40% falls during November through January. About 40% of the precipitation falling in the months of December through February is snow or sleet.

3. BUILDING DESCRIPTION

3.1 Structural

A simplified floor plan of the 306-W Building is shown in Figure 2. The 306-W Building has approximate dimensions of 193 feet in the east-west direction and 160 feet in the north-south direction. The first floor (laboratories and shop area) has about 32,000 square feet of floor space of which about 30,000 is high-bay area with a ceiling height of 25 feet. The remaining portion of the first floor is office area and has a ceiling height of eight feet. The second floor, consisting of offices and an equipment room, has about 2,000 square feet of floor space. The ground elevation of the building is 392 feet above mean-sea level.

The building is of steel construction with a tar and gravel roof over steel decking. A 12-inch thick concrete firewall divides the building into approximately equal 306-E and 306-W portions. This wall has a sealed personnel door and a large, steel sealed equipment door. Both doors have a 1-1/2 hour UL fire rating. The 306 Building was designed in compliance with the Uniform Building Code with provisions for resistance to natural-force loadings stipulated for this geographic area, principally simultaneous earthquake accelerations of 0.125 g horizontally and 0.083 g vertically (Modified Mercalli intensity VII) and a wind speed of 85 mph, with a safety factor of 2.5 based on ultimate strength of the structural steel.

3.2 Heating, Ventilating and Air Conditioning (HVAC)

A simplified diagram of the ventilation system for the first floor of the 306-W Building is shown in Figure 3. The 306-W high-bay area and laboratories are maintained at a slightly negative-to-atmosphere pressure. Independent ventilation systems serve four distinct areas within 306-W.

- The first floor office space is served by a recirculating refrigerated unit with internal heaters controlled in the HVAC enclosure south of the main building.
- The second story office section along the south side is served by two roof top units which provide ventilation, heating and refrigerated cooling on a partial recirculating basis.
- The main high bay research area single pass supply air is provided through independent roof mounted H & V units consisting of pre-filters, steam heating coils and an evaporative cooling section. Exhaust from this section is discharged through three roof mounted exhaust systems which include medium efficiency pre-filters and one stage of HEPA filtration. Vacuum air samplers are installed in the exhaust air ducts to sample air exhausted to atmosphere.
- The air flow through the ceramics fuel laboratory (located in the northwest corner of 306-W, Rooms 126, 127 and 128) is shown in Figure 3. The laboratory receives supply air through a single-pass refrigerator HVAC system. The exhaust air is discharged through two stages of HEPA filters by an exterior mounted fan located at the northwest corner of the facility. A vacuum air sampler is installed in the exhaust duct to sample

air exhausted to the atmosphere. Equivalent ventilation will be furnished for the Thorium Oxide Fuel Development Laboratories (TOFDL) to be created by extending the Ceramics Laboratory into the space bounded by building columns D4, E4, D10 and E10, Figure 2.

The present ventilation system represents an upgrading of the ventilation system for the high bay areas where minimal filtration had been previously provided. With the old ventilation system, air sampling was routinely done at three specific locations in the building; the bag filter in the Specialty Shop, the oxide conversion glove box, and the Thorium Storage Room.

CY-1977 gaseous effluent data as determined from these air samples are summarized in Table I.

TABLE I

1977 Radioactive Release Data* - 306-W Building

<u>Sampler Location</u>	<u>Average Release Concentration, $\mu\text{Ci/cc}$</u>	<u>Total Release for CY-1977, Ci</u>
Bag Filter	1.3×10^{-13}	4.0×10^{-5}
Oxide Conversion Glove Box	4.2×10^{-14}	8.4×10^{-6}
Th Storage Room	9.0×10^{-15}	3.5×10^{-6}

*Based on natural uranium β -activity

The installation of the new ventilation system has provided the capability to sample total building gaseous effluents rather than sampling of releases from specific locations. Except for the Ceramics Laboratory, the gaseous effluents from the high bay areas are sampled at the three exhaust ducts on the roof. Since the areas being sampled with the new and old ventilation and sampling systems differ, sampling data from the two sections are not comparable. The new air samplers were placed in service on November 10, 1977. Release data accumulated through June 15, 1978, are summarized in the following table.

TABLE II
1978 Radioactive Release Data* - 306-W Building

<u>Sampler Location</u>	<u>Average Release Concentration, $\mu\text{Ci/cc}$</u>	<u>Total CY-1978 Release up to June 15</u>
Roof #1 Exhaust	5.9×10^{-15}	9.8×10^{-7} Ci
Roof #2 Exhaust	4.5×10^{-15}	4.8×10^{-7} Ci
Roof #3 Exhaust	3.1×10^{-15}	6.5×10^{-7} Ci

*Based on natural uranium β -activity

The average release concentration given in Table II for the high bay areas of the 306-W Building are well within BNW's ALAP goal of 1% of the values in Table II of DoE Manual Chapter 0524.

A fourth sampler was placed in service August 1, 1978 in the exhaust duct for the Ceramics Laboratory. Insufficient data have been accumulated to make a meaningful evaluation of the radioactive release at this sampler.

3.3 Electrical

The 306-W Building is served by a 2400/480 volt, 1500 kVA, 3-phase outside transformer and inside transformers reducing the 480 volts to 240 and 120. The 480 volt transformer is cross-tied to the 306-E 480 volt transformer. The 306 Building (both the east and west sides) is supplied with emergency electrical power (480 V, 30 kVA) for emergency lighting and the alarm systems described in Section 3.4 below.

3.4 General Building Alarms and Monitors

Manual fire alarm boxes and audible fire alarms in the building are connected with the 300 Area fire alarm systems. The building is equipped with automatic fire suppression sprinklers, and the activation of any sprinkler head sounds an alarm in the 300 Area Fire Station.

Criticality alarm protection for the 306-W Building is provided by a system that covers both 306-W and 306-E (HEDL). This system has five strategically located neutron-sensitive heads (two in 306-E and three in 306-W) with the comparator panel located in 306-W. The location of these detectors is shown in Figure 2. This system alarms in both 306-E and 306-W and is connected to a central annunciator panel at the 300 Area patrol headquarters. The alarms will activate when two or more of the five monitoring instruments exceed the set limit of 9.3 mrad/hr. Also, if any criticality detector fails, a distinctive failure alarm sounds at the comparator panel located in 306-W. Three passive criticality dosimeters are located in strategic areas for the determination of post-accident neutron and gamma doses.

Continuous air samplers for determining concentration of α and β emitters, are located throughout the 306-W Building as follows -- the SNM storage facility (Room 123) contains two samplers, two air samplers are in the Specialty Shop, there is an air sampler in Rooms 126 and 127 of the Ceramics Laboratory, one in Room 125, two in Room 120 and one more on the roof.

A hand-and-shoe counter is located at the main entrance to the high-bay working area and at the exits from the Specialty Shop and the Ceramics Lab.

The building is served by an evacuation siren. A telephone connected to the BNW crash alarm system is available for receipt of emergency instructions and information.

3.5 Mechanical

The building's permanent equipment includes the following seven electromechanical or mechanical cranes:

- The Ceramics Lab is served by a 1-ton bridge crane that travels in the east-west direction.
- Room 129 (high-bay) is served by a 2-ton remote control bridge crane that travels in the east-west direction.
- Rooms 125, 124, 120, 121 and the Specialty Shop are each served by 1-ton bridge cranes that travel in the east-west direction.

3.6 Services

The following piped liquids and gases are available in the building where needed:

- Sanitary water -- hot and cold.
- Process water.
- Compressed air -- 15 and 100 psig.

- Propane gas at 15 psig pressure is piped into 306-W from 1,000-gallon capacity tank located outside the north side of 306-W.

The building contains two separate sewer systems -- one for the sanitary waste and the other for the process waste. The high bay (laboratory) portion of 306-W is serviced by trenches running west to east the length of the building. These trenches drain into 3 x 2.5 x 3 ft sumps which in turn drain to a 6-inch main line under the 306-E Building. The 6-inch line drains to the major 300 Area 24-inch sewer line. The 24-inch line discharges to the north process trench.

All laboratory sinks that could be used to rinse contaminated equipment or for disposal of radioactive material have been capped. Liquids that cannot be properly discharged to one of the sewer systems are collected in drums and removed for disposal.

3.7 Fire Protection

The building is completely covered by an automatic wet-pipe fire sprinkler system. Hand-held extinguishers of appropriate types are located throughout the building in accordance with the NFPA code requirements. The 300 Area fire trucks arrive within three minutes after an alarm or a call.

3.8 Security

The building is located within a Limited Access Area. Personnel normally enter the building through any of several personnel doors located on the west and north sides of the

building. These doors are locked after the day shift and may be entered then only by employees with keys. A personnel door and an equipment door are located in the wall which separates 306-E and 306-W. These doors are for emergency use only and are locked and sealed. They may be opened only under the supervision of the Building Manager, except in emergency situations when they may be opened by anyone if necessary. All outside personnel doors are equipped with crash-bar hardware.

4. NUCLEAR SAFETY LIMITS

The Nuclear Safety Limits stated in this section are binding. Material presented elsewhere is intended to be descriptive of, or justification for, the Nuclear Safety Limits. Other restrictions given in this report are examples of those set forth in Criticality Safety Specifications and Radiation Work Procedures, presented for description purposes, and subject to change within the boundaries of the limits stated here. Any change in operations or equipment that introduces an unreviewed safety question, or significantly increases the probability or consequences of an accident discussed herein, shall require an addendum to the Safety Analysis Report. Operations involving plutonium (other than sealed sources) would constitute an unreviewed safety question.

All fissionable material operations shall be controlled by engineered safeguards and procedural controls such that a two-contingency policy* is satisfied. Fissionable materials may be handled in any physical or chemical form. Criticality Safety limits shall be established at fractions of the critical parameters for the specific material that provide a safe margin, commensurate with uncertainties of application of measurements and calculations. Methods of calculation shall be shown to give accurate or conservative results when compared to experimental measurements.

The Nuclear Safety Limits are:

- 4.1 Fissionable material operations based upon mass control shall be limited to 45% of a critical mass. The critical mass

*The 2-contingency policy states that at least two unlikely, independent, and concurrent accidents, failures, or limit violations must occur before criticality is possible.

shall be based upon the physical, chemical and isotopic form of the fissionable material. Quantities of moderator permitted, geometries of components or containers, or fixed arrangement of the fissionable material may be considered. If inadvertent entry of a moderator is credible, a mass limit shall be established that precludes criticality should the inadvertent entry occur. Where geometry of a component is varied during a process or operation (e.g. a machining operation), the mass limit is based upon the optimum geometry for criticality through which the material is varied.

4.2 Geometry control is exercised by physically restricting the volume or dimensions of the fissionable material. The physical limitations are based on the fissionable material being of optimum concentration or moderation and full water reflection. The physical limits are:

- 75% of the critical volume.
- 85% of the critical slab thickness.
- 85% of the critical cylinder diameter.

4.3 A fixed storage array shall be limited by either:

- Mass controls specified in Limit 4.1.
- Geometry controls specified in Limit 4.2.
- The K_{eff} of the array shall not exceed 0.95 with all storage positions loaded to the specified limit and with optimum interspersed moderation and full water reflection. No single loading error of a storage position shall result in a criticality.

- 4.4 Limits on spacing between batches of fissionable materials, process vessels or containers containing fissionable materials, and fissionable material being transported past other fissionable material, shall comply with the 2-contingency policy and shall be established by a technical analysis. Fissionable materials not separated by a specified safe spacing shall be considered to be parts of the same batch.

5. ORGANIZATION AND GENERAL ADMINISTRATIVE CONTROLS

This section describes the overall management and administrative control responsibility for the BNW portion of the 306 Building (306-W). Detailed management and administrative controls for each operation are described in the safety analysis of those operations (Section 6).

5.1 Management

The 306-W Building is a multipurpose facility containing varied activities of the Materials Department and the Specialty Machine Shop, Craft and Operation Services Department, Operations and Services and the Chemical Technology Department.

The Materials Department Building Manager, through his resident Facilities Specialist, has the overall responsibility for the safe and effective use of the 306-W Building. This responsibility includes integrating the efforts of all occupants and support groups to provide a safe building which meets all BNW and DoE requirements. BNW supporting components are Occupational and Environmental Safety, Quality Assurance, and Craft Services.

5.2 Administration Controls

Administrative controls are prescribed 1) to ensure a high degree of safety to personnel, equipment and property, and the public; and 2) to meet applicable DoE regulations and requirements. These administrative controls are formulated in accordance with BNW Management Guide and appropriate BNW manuals. The controls are considered effective requirements that provide safe operations within the 306-W Building. Administrative controls are:

5.2.1 Criticality Safety Specifications

Criticality Safety Limits and Controls for handling, storing or transporting fissile material within the 306-W Building shall be specified in Criticality Safety Specifications (CSS) that conform with the requirements given in Criticality Safety Procedures, BNWL-MA-25. Criticality Safety Limits are established by a technical review and analysis of the operation by the Nuclear Criticality Section.

5.2.2 Criticality Safety Audits

All procedures that affect the Criticality Safety of the 306-W operations are periodically audited by prescribed Operating and Nuclear Safety personnel to insure compliance with the requirements of the CSS and the SAR. The audit program shall comply with the requirements specified in BNWL-MA-25.

5.2.3 Training Program

The training program for personnel working in the 306-W Building shall comply with the requirements of Procedure No. 7, "Criticality Safety Procedures," BNWL-MA-25. Except for the Ceramic Laboratory and the Uranium Storage Facility, enriched uranium is infrequently handled. Therefore, those not working with fissile material need not participate in the training that is required of fissile material handlers. If additional fissile material handlers are required for a specific

job, special training will be given to qualify them for the handling of fissile material. The training and testing will be required to cover information pertinent to the safe conduct of the assigned task.

5.2.4 Labeling and Posting

Procedure No. 5, BNWL-MA-25 specifies posting and labeling requirements for maintaining proper identification of fissile materials. The enrichment of materials being introduced into the 306-W facility is validated in accordance with Nuclear Materials Management Procedures, BNWL-MA-5.

5.2.5 Emergency Procedures

Emergency procedures are maintained for the 306-W Building in accordance with BNW Management Guide requirements.

5.2.6 Radiation Protection

Where applicable, Radiation Work Procedures are in place in accordance with requirements of "Radiation Protection Procedures," BNWL-MA-6. Potential exposures to personnel are projected for each program or project involving radioactive materials. The maximum exposure to an individual in CY-1977 occurred in the Ceramic Laboratory operations and was as follows:

Extremity	250 mrem
Skin	250 "
Whole Body	160 "
Penetrating	160 "

An "Environmental Impact Assessment" (EIA) is also prepared that evaluates a program or project for potential accidental and routine releases of radionuclides from the facility. Included in the EIA are the potential maximum individual dose and the dose exposure to population within a 50-mile radius.

5.2.7 Waste Management

Waste Management Manual, BNWL-MA-8, provides guidance and requirements for the safe management of radioactive waste and nonradioactive noxious waste.

5.2.8 Industrial Safety Hazards

Analyses of industrial safety hazards that are not contributive to accidents involving radioactive materials are provided, where appropriate, in Operational Safety Analysis Reports (OSARs). OSARs are prepared by the responsible scientist and are reviewed and approved by BNW Industrial Safety. OSARs may require approval by the BNW Safety Review Council where the consequences of an occurrence may be significant.

5.2.9 SS Material Transfers

In accordance with BNWL-MA-81, shipments of SS material from sources outside PNL shall be received only by the Material Control Custodian for the Material Balance Area (MBA) receiving the shipment, or by a formally authorized alternate material control custodian. Similar requirements are in force for SS material transfers between PNL Material Balance Areas (BNWL-MA-5, Procedure No. 4).

Three MBAs (with their respective custodians and alternates) have been established for the 306-W Building. These are:

- Diversified Metal Working Facility - Materials Development Section.
- Ceramics Laboratory - Fuels Design and Development Section.
- Specialty Shop - Craft and Operation Services Department.

6. SAFETY ANALYSIS

6.1 Diversified Metal Working Facility

6.1.1 Organization and Administrative Controls

6.1.1.1 Responsibilities

The Material Development Section, Materials Department, has the responsibility for the safety of the work in the Diversified Metal Working Facility.

Review of the operation will be carried out by the Nuclear Criticality Section and the Safety and Nuclear Materials Management Section (in the preparation of the Criticality Safety Specification) and by the Radiation Monitoring and the Radiation and Standards Engineering Sections (in the preparation of the Radiation Work Procedure). Radiation monitoring personnel will be called upon to establish dose rates and to survey for contamination.

The Materials Development Section will be audited for compliance with written BNW safety procedures for the 306 Building.

6.1.2 Description

6.1.2.1 Facility Description

The Diversified Metal-Working Facility occupies Rooms 109, 110, 111, 120, 121, 124, 125 and 129 of the 306-W Building (see Figure 2). The laboratory currently contains the following major pieces of equipment:

Two rolling mills

Isostatic press

Vibratory compactor

Grit blaster

Vapor degreaser

Two hydraulic Universal testing machines

Hot hardness testing

Electroslag-submerged arc welding

Electron beam welding

TIG and MIG welding equipment

Resistance welding

Equipment for hot gaseous HF treatment
of metal scrap

Aqueous cleaning of metal scrap

Inductoslag melting (induction melting in
water-cooled copper crucible)

Forging hammer

Two draw benches

Press brake and shear

Six utility presses

One high energy rate forming and compaction
machine

Four swages

Stretch straightener

Three roll straighteners

Arc button furnace

Tungsten resistance furnace

Vacuum induction furnace

Inductoslag melting furnace

Four glow bar furnace and utility heating

One endothermic gas generator

Numerous resistance furnaces

Quench tanks

Two cold-wall high temperature vacuum furnaces

6.1.2.2 Process Description

The Diversified Metal-Working Facility performs a variety of nonrepetitive fabrication development jobs using one or more items of the equipment items listed above.

Melting is performed in vacuum or inert gas chambers with the vacuum pumps exhausting to the building exhaust system. Iron, nickel, uranium and zirconium base alloys are melted in sizes from a few grams up to 40 kgs uranium equivalent using ceramic, graphite or water-cooled crucibles and molds.

Metal deformation and heat treating processes such as forging, extrusion, rolling, swaging compaction and drawing involve the handling of metal pieces from a small wire up to billets weighing 40 kgs or more and at temperatures up to 1200°C. Handling of these materials is usually performed using hand-held tongs, hydraulic carts and overhead crane.

Encapsulation methods are used on hot operations such as extrusion, heat treating and compaction involving powders and/or radioactive materials.

Some chemical operations are performed to remove lubricants and oxides from metal surfaces or to remove metal mandrels and encapsulating materials such as copper or iron. These involve the use of solvents, aqueous solutions, and hot HF gas*. Fumes from nonradioactive operations are directed to a scrubber system. Fumes from radioactive chemical operations are directed to the building exhaust system.

Room 120 of the 306-W Building is currently being used as a unit operations laboratory for research in various chemical processes related to the reprocessing of nuclear fuels. Only work with depleted uranium will be done. This laboratory has thus been provided with the appropriate storage tanks (1,000 gallon), piping, associated pumps, etc., which are required for this purpose. In addition, the utilities such as water, steam, power, etc. are provided at capacities suitable for a unit operations laboratory.

The various experiments completed, underway, and contemplated required the use of strong acids (nitric acid), preparation of uranyl nitrate solutions of various concentrations, the containment and treatment of evolved nitrogen dioxide containing gas streams, etc. The majority of the support equipment necessary to complete

*Section 5.2.8 - Industrial Safety Hazards

these operations is now available in the room. Specific experimental equipment for individual experiments is readily assembled and appropriately installed in the facility. Examples of specific experimental work which can be completed includes evaporation of uranyl nitrate solutions to produce products suitable for calcination to uranium dioxide, liquid extraction experiments, nitrogen oxide recovery to produce acid for recycle, and other similar studies related to nuclear fuels reprocessing.

Because specific experiments will change from time to time, the basic laboratory equipment is designed to be as flexible as possible. The room can thus be modified to accept a variety of unit processes at a relatively modest cost in labor and hardware.

6.1.3 Hazards

6.1.3.1 Criticality Safety Control

The potential for an accidental criticality event depends not only on the amount of fissionable material present at a work location, but also on other factors such as density, geometry, materials admixed or alloyed with the fissionable material, and neutron reflection by surrounding media. Any work involving fissionable material in the Diversified Metal Working Laboratory will be conducted within the limits of a Criticality Safety Specification (CSS) that establishes two contingencies of protection on the work. The technical limits for the CSSs are established by the Nuclear Criticality

Section by means of a review and analysis of the planned work. These limits must fall within the envelope of the Nuclear Safety Limits given in Section 4. The operating group has the responsibility for the preparation of the CSSs, however, the CSSs must be reviewed and approved by Safety and Nuclear Materials Management and the Nuclear Criticality Sections.

For most types of work performed in the Diversified Metal Working Laboratory, the primary means of establishing two contingencies of protection are:

- mass control, and
- geometry control

Where practicable, operations with fissionable material are conducted such that criticality is precluded by geometry. Material restricted by a safe geometry based upon optimum moderation and full reflection cannot achieve criticality regardless of its physical state, degree of moderation or reflection. However, due to the size and design of the equipment within the Diversified Metal Working Laboratory, the most prevalent means for establishing the required criticality control is by setting a limit on the mass of fissionable material processed at

a location or work station. Where mass limits are established they are normally based upon 45% of the critical mass. Thus an error violating a mass limit would require more than a double batching error before criticality would be possible, not probable, but possible. If moderator control is used to provide a contingency of protection in conjunction with a mass limit, the mass limit may be established at 90% of the critical mass assuming optimum moderation and full reflection (MCM). The mass limit established at 90% MCM shall also be restricted to $\leq 45\%$ of the critical mass with permitted quantities of moderator present. Thus for criticality to be possible, two independent errors would be necessary -- 1) a mass limit exceeded, and 2) the inadvertent intrusion of moderator into the material. Where moderator control provides a contingency of protection, measures shall be taken to prevent the intrusion of a moderator, i.e., sealed vessels and containers or the source of the moderator physically prohibited.

It is recognized that a violation of a mass limit can more likely occur if the limit is stated in terms of fissile (^{235}U) weight.

This is particularly true when the material is not uranium metal, but an alloy, cermet or ceramic containing uranium. Thus, in practice, mass limits will be translated into the weight of material being handled directly verifiable by scale weight without calculation. Under such conditions the personnel handling the material quickly become accustomed to the physical size of an allowable batch of material.

Spacings between batches of fissionable material and work stations is established in accordance with Criticality Safety Specifications. Spacing requirements, along with the basic limits that provide the two contingencies of protection, are posted in a location that is readily visible to operating personnel. Labels are provided on containers that identify the material and the contained mass throughout the processing operation. Each work station or temporary holding station will have posted current inventory of fissionable material at that location, recording each addition and removal to and from the station.

Processing fissionable material to finished form involves some material loss, normally much less than about 1%. Much of

this material is buried in dry waste (gloves, wipes, dust filters, etc.). Some material may accumulate in places such as HEPA filters, etc. Procedures are in force that include mandatory daily clean-up of the equipment and work area plus individual equipment clean-up after each use. Other procedures are in force that require periodic inspection of waste drain lines and sumps within the 306-W facility for possible accumulations of materials. For compliance with nuclear material management requirements, additional inspections for possible accumulations are made whenever "materials unaccounted for" values exceed amounts dependent upon measurement uncertainties. These amounts are small fractions of a minimum critical mass.

Although the possibility of a criticality accident in the Diversified Metal Working Laboratory cannot be precluded, acceptable means of establishing a minimum of two contingencies of protection on fissionable material operations have been applied. The limit and controls in force on these operations have historically demonstrated a sufficiency for reducing the probability of a criticality accident to an acceptable level.

6.1.3.2 Uranium Melting

(1) Criticality

Adequate criticality safety control for melting uranium materials is provided by the nuclear safety limits specified in Section 4. The uranium material melted in a furnace will not contain any hydrogenous material. However, a coolant leak could be the source of inadvertent entry of water into the fissionable material. If the criticality control for such a melting operation is established on a mass limit, the limit shall be 90% of the minimum critical mass (MCM) for that material, i.e., optimum moderation and full reflection by water in spherical geometry. For operations where more than an MCM is required to be present in the furnace at one time, the geometry of the furnace shall be restricted to that of a safe geometry. This is done through an analysis of the casting operation by the operating group and the Nuclear Safety Section. This analysis includes establishing the size and shape of the

crucibles and molds as well as ensuring that a safe geometry would be maintained in the event of any conceivable accident (such as crucible or mold fracture during melting or pouring). Fissionable material in safe geometry provides a higher degree of safety than a safe mass limit with administrative spacing control. This is because the safe geometry is that for fully reflected, optimumly moderated materials. Material restricted to a safe geometry cannot attain criticality regardless of its physical state, degree of moderation or reflection.

For criticality to occur in a vacuum furnace operation, it would necessitate over-batching a mass limit and the concurrent inadvertent intrusion of water into the furnace. Because of the nature of the vacuum furnace operations, it has been the practice to be over-conservative by establishing the mass limit at 45% MCM rather than the 90% MCM value. Thus exceeding a double-batching situation in itself provides

two contingency protections on the operation and the additional criteria of water intrusion is a third contingency of protection. Furnaces that are safe by geometry cannot be made critical. Thus it is concluded that criticality is not conceivable in a vacuum melt furnace designed or controlled within the envelope of the nuclear safety limits of this SAR.

(2) Explosion

In a typical uranium melting operation, the amount of molten metal ranges from 100 grams to 40 kgs. In all cases, water cooling is in close proximity to the molten uranium. A water leak during uranium melting could result in a reaction between the water and uranium. This reaction could result in the water flashing to steam and the evolution of hydrogen. A breach of the melting chamber would allow hydrogen to enter the working area resulting in a possible explosive mixture.

The following operating procedures and engineered safety features are used to minimize the possibility of an explosion.

- Uranium melting is performed with an operator present at all times from power on to solidification of the ingot.
- The chamber is evacuated before the melting power is turned on. Should there be a water leak at this time it will be detected during pumpdown.
- A water leak occurring after the melting power is turned on will be detected by a rise in furnace pressure or by the operator's direct observation of the molten metal, at which time the heat is aborted by turning off the melting power and cooling water supply. The furnace power and cooling water can be turned off in less than 5 seconds.
- For enriched uranium heats an audible alarm is electronically linked to the chamber pressure sensors so that a rise in chamber pressure sounds the alarm. The operator can then turn off the melting power and cooling water. For these heats operator attendance is required until the ingot and furnace have cooled to below incandescence.

6.1.3.3 Release of Uranyl Nitrate Solutions to the Process Sewer System

Accidental leakage of large volumes (up to 1000 gallons) of acid/uranium solutions containing up to several hundred kg of depleted uranium from the equipment in Room 120 of the 306-W Building is unlikely, however the consequences of such an event should be discussed. If such an accident should occur, the solution would be contained by a 6-inch high curb on the floor around the tanks. The volume of the curbed zone is at least equal to the volume of the largest tank. Drainage would be confined to the Room 120 floor drains which are connected to the process sewer system. The discharge route for the Room 120 drain system is through 4-inch Duriron line to a concrete sump located in the Specialty Shop, Room 121. The sump discharges through 4-inch line and connects with the 6-inch main building discharge line on the 306-E side of the building. The discharge may be observed from a manhole approximately 40 feet south of the building. From this point the process sewer proceeds east parallel to the 306 Building and connects with the major 300 Area 24-inch sewer line. The 24-inch line discharges to the north process

trench. Sampling stations are located just ahead of the discharge into the process trench. These sampling stations are maintained by the Hanford Engineering Development Laboratory (HEDL). Monitors are to be installed in the two process sewer sumps serving the TOFDL by January 1979. One other monitor will be installed during CY-1980 just outside the 306 Building to monitor both PNL and HEDL discharges to the process sewer.

One of the conclusions reached after the accidental leakage of 847 gallons of HNO_3 containing 121.5 kg of depleted uranium was that the release of the lost uranium to the trench would not exceed the limits of ERDAMC 0524 Appendix, Annex A, Table II, i.e., 4×10^{-5} $\mu\text{Ci}/\text{m}$, under any credible release rate.⁽³⁾

It is therefore concluded that the accidental release of acid/uranyl solutions from the equipment in Room 120, to the process sewer system poses no radiological hazard.

6.2 Ceramics Laboratory

6.2.1 Organization and Administrative Controls

6.2.1.1 Responsibilities

The Fuels Design and Development Section, Materials Department (or in the future other officially named organization/s) has the responsibilities for safety of work in the Ceramics Laboratory; e.g., powder processing, rod fabrication, bundle assembly, etc. Review of the planned operations will be carried out by the Nuclear Criticality Section and the Safety and Nuclear Materials Management Section (in the preparation of the Criticality Safety Specification) and by the Radiation Monitoring Section (in the preparation of the Radiation Work Procedure). Radiation monitoring personnel will be called upon to establish dose rates and to survey for contamination.

Fuels Design and Development will be audited for compliance with Criticality Safety requirements by the Safety and Nuclear Materials Management Section and by the Criticality Safety Representative for the 306 Building.

6.2.1.2 Administrative Controls

Specific administrative controls applicable to the Ceramics Laboratory are posted at the door separating the laboratory from the remainder of the building. Included are notices that:

- No fissile material shall be brought into the laboratory without approval of the room monitor.
- The laboratory contains a sink connected to the process sewer, however the sink is not used for washing contaminated equipment or for disposal of any radioactive material. The sink is posted to indicate this limitation on its use.

6.2.2 Description

6.2.2.1 Facility Description

General

The Ceramics Laboratory occupies 2400 square feet in Rooms 126, 127 and 128 (northwest bay) which is separated from the rest of the building by a sheet-metal wall. The room is bounded by building columns D-1, E-1, D-4 and E-4. The Ceramics Laboratory has four sections -- two partially enclosed areas for powder processing, rod welding, leak checking and inspection; a totally enclosed area for additional UO_2 processing; and an airlock near the west entry which leads to the outside of the building. The laboratory is free of overhanging equipment except for a 1-ton bridge crane.

In preparation of the Alternate Fuel Cycle Program, the Ceramics Laboratory facilities are being modified and extended to include space bounded by building columns D-4, E-4, D-10, and E-10. This space, approximately 7200 ft², will be called the Thorium Oxide Fuel Development Laboratory (TOFDL). The operations conducted in this space will be similar to those performed in the existing Ceramics Laboratory. Thoria and urania powders, or sol-gel microspheres will be comminuted, mixed and granulated to form process feed material for compacting into pellets and sintered to hard, dense oxides. Uranium used in the process will be either natural or depleted in uranium-235 content; enriched uranium may be used for pellets scheduled for irradiation in a nuclear reactor. Thoria or urania powders and the sol-gel microspheres for the TOFDL operations will mainly be procured from outside suppliers. However, approximately one kg/day of feed material may be produced within the TOFDL through bench scale conversion of uranium and thorium nitrate solutions; similar development work has been previously performed in the Ceramics Laboratory. The processes for converting the nitrate solutions to oxide are thermal decomposition of (1) precipitates of the oxalate, and (2) anhydrous salt from freeze drying the nitrate solution.

Effluent control requirements for the TOFDL will be equivalent to those described for the existing Ceramics Laboratory, e.g. double HEPA filtration for exhausted air and direct connection of sinks to collection drums. Uranium and thorium materials for the TOFDL will be stored in Room 123, the SNM Storage Area. Enriched materials in excess of safeguards limitations for the 306-W Building may be stored in the nearby 303-C Building, the approved PNL Special Nuclear Materials Storage Facility.

The TOFDL (as well as the rest of the 306-W facility) is not designed to handle plutonium or other highly radiotoxic materials. The work done on these fuel cycles will be conducted using stand-ins or substitutes such as stable cerium oxide for plutonium; stable cobalt, cesium, and niobium for gamma spikes; and ^{235}U or ^{238}U for ^{233}U . Most, if not all, work in the TOFDL will involve uranium and thorium under standard radiation protection and criticality safety requirements.

The TOFDL will have a staff of about 12 and will have a 3-year life expectancy. The following systems will be provided as a part of the project:

- Approximately 23 open-face hoods and/or modified glove boxes

- Double High Efficiency Particulate Air (HEPA) filtration throughout with associated sampling systems
- Personnel decontamination area
- Personnel airlocks
- Vacuum room air sampling system
- Utility extensions
- Liquid effluent sampling system

Where warranted, the release of short-lived radiogases will be reduced as much as possible through the use of locally installed activated charcoal systems.

The Environmental Impact Assessment for the TOFDL⁽¹⁵⁾ has concluded that there are no adverse or environmental impacts. Calculated radiation doses to the public and employees from routine operations are orders of magnitude lower than doses received from natural background sources. Postulated worse-case TOFDL accident total body, maximum individual doses (1×10^{-7} mrem/yr) were many orders of magnitude less than the applicable standard (5×10^{-2} mrem/yr). Analyses for postulated accidents that lead to this conclusion are presented in Section 6.5 -- "Consequences of Accidents." It is, therefore, concluded the routine operations or an unlikely accident in the TOFDL will not pose additional risk to the health and safety of employees or the public.

Control of Personnel and Operations
Near Ceramics Laboratory

BNW controls the entire 306-W Building and equipment west of column line 10 (Figure 2) and can maintain effective regulation of personnel and activities adjacent to the Ceramics Laboratory. Signs are posted at all external BNW access doors stating that no fissionable material may be brought into the building without the prior approval of the facilities management. The external west entry is locked at all times except when in use. Keys are issued only to persons having a need for direct entry to the Ceramics Laboratory.

Ventilation System

The air supply for the Ceramics Laboratory (Rooms 126, 127 and 128) is separate from the rest of the building and is humidity controlled. All air is exhausted through the hoods and is drawn through two sets of HEPA filters to a stack on the west end of the building, Figure 3. Air flow at the hood face is maintained at a minimum 150 ± 25 linear feet per minute. The air flow is checked quarterly. The exhaust fan does not have a backup unit or emergency power. In event this fan stops for any reason, special lights will come on at both entrances to the

laboratory and access will be limited, until the laboratory is surveyed and the system is restarted either automatically or manually. The air supply system and the exhaust system normally shut down and automatically restart together. If the system restarts automatically, the warning lights stay on until manually reset, following a contamination check of the laboratory by radiation monitoring. The exhaust fan, safety interlocks and warning lights are on Craft and Operation Services preventive-maintenance schedule.

Air Filtering and Sampling

Exhaust air from furnace canopy travels directly to the secondary filters. One set of primary filters is near the hoods, and a large bank of secondary filters is just outside the building. These filters have been DOP tested (aerosol tested) in place and have been found to be 99.99% efficient for particles 0.3 micron diameter or larger. (Only a fraction of 1% of the powder handled will have particle size below 0.3 micron). The DOP test will be repeated annually by BNW air balance personnel following, as in the original test, RDT Standard F3-34. Air balance personnel will also monitor the air flow in the hoods each quarter and the pressure drop across the filters each month.

Air sampling is performed by Radiation Monitoring at the stack (past the final filters) by removing and counting filter-paper samples each week. A portable unit samples room air when $> 50\%$ enriched UO_2 is being processed. The air sampling unit draws ~ 1 CFM, and alarms if the concentration of α -emitters exceeds permissible limits. The concentration is recorded by a chart recorder.

Fire Protection

Fire protection is provided by the existing overhead sprinkler system which is actuated by fused links at the ceiling level. Fire alarms will sound if the sprinklers are actuated.

6.2.2.2 Process Description

The principal material processed in the Ceramics Laboratory is uranium dioxide (UO_2). Natural, depleted, and enriched (to as high as 93% ^{235}U) UO_2 may all be present in the laboratory at one time. Typically, UO_2 is received in powder form and is converted to nuclear fuel pellets by a series of processing steps which may include part or all of the following:

Weighing, blending, screening, hammer milling, ball milling, wet or dry binder addition, drying, slugging (pre-pressing), granulating, pellet pressing, hole drilling, sintering, centerless grinding, ultrasonic cleaning, drying.

All handling of UO_2 and ThO_2 in powder form is limited to hoods.

The uranium may also be received in the form of dried ammonium diuranate (ADU) which is simultaneously calcined and reduced in a hydrogen or hydrogen-argon atmosphere furnace, yielding UO_2 powder suitable for the processing operations already described.

Occasionally sintered UO_2 pellets may be recycled to the powder form by oxidizing to U_3O_8 in an air atmosphere furnace, followed by hydrogen reduction to reconvert the resulting powder to UO_2 .

In some cases, the UO_2 powder may be blended with other nonfissile oxide powders such as ThO_2 , Ga_2O_3 , ZrO_2 , etc. and formed into sintered mixed oxide pellets.

Loading of fuel pellets into cladding tubes and welding of end caps in the tubes is performed in a vacuum welding chamber. The

fuel rods are loaded into special capsules for irradiation in a nuclear reactor. Alternately they are packaged separately or formed into fuel rod assemblies for use at other laboratories or reactors.

Fuel pellets may also be packaged for shipment to other locations for assembly into fuel rods or assemblies.

Another type of processing that may occur in the Ceramics Laboratory is the receipt of unirradiated reactor fuel assemblies from another site, followed by disassembly into fuel rods and removal of fuel pellets from the rods. The pellets may then be reloaded into rods having characteristics different from those in the fuel assemblies received from offsite.

6.2.3 Hazards

The hazards discussed below are those which relate to a potentially significant radiological incident, as defined by BNWL-MA-25, Procedure 4. These include 1) criticality, and 2) fires or explosions severe enough to breach the building and disperse kilogram quantities of enriched uranium to the environs.

6.2.3.1 Criticality Controls and Contingencies

(1) Fissile Material Description

The total quantity of fissionable material in the Ceramics Laboratory at any given time may amount to several minimum critical masses (MCMs). The material will normally exist as uranium or thorium oxide powder and pellets. However, small amounts of material may exist in other chemical and physical forms, such as ADU, carbides, metal, etc., in chunks, slurries, or solutions. The total amount of enriched material in the 306-W Building is not limited by criticality safety considerations; however, in practice, the amount of U-235 contained in uranium enriched to 20% or more is restricted to a Category III A quantity, DOE Order 5603.2, which is less than a critical mass for unmoderated material.

(2) Criticality Potential

The presence of large quantities of fissionable material in the Ceramics Laboratory allows the possibility that a critical configuration could inadvertently be assembled.

(3) Criticality Specifications and Controls

Any work involving fissionable material in the Ceramics Laboratory will be carried out under the limits and controls of Criticality Safety Specifications (CSSs). As described in Section 5.2, the CSSs are prepared by the operating group and approved by Nuclear Safety and Nuclear Materials Management. The technical limits for the CSSs are provided by the Nuclear Criticality Section, using conservative interpretation of existing data. These limits assure that the 2-contingency policy is met.* Added controls (such as spacing requirements) are written into the CSSs to assure compliance to the technical limits.

Credit is taken for the ^{235}U enrichment of the uranium in establishing criticality limits. Since all the basic criticality parameters are sensitive functions of enrichment, a brief discussion of enrichment control is in order.

*The 2-contingency policy is based upon the incorporation of sufficient safety factors such that at least two unlikely, independent and concurrent events must occur before criticality is imminent. In other words, a single failure or breach in procedure cannot result in a criticality incident.

- Containers for enriched UO_2 are color-and-size coded for ease in identifying enrichments (see Section 6.4 for further discussion).
- Inventory sheets for work stations and storage arrays will have the enrichment limit clearly marked at the top, and enrichment shall be part of the required information for each entry.

(4) Criticality Contingencies

(a) Contingencies Arising from Normal Operations

Most contingencies for accidental criticality involve a departure from normal operating conditions. Two classes of contingencies which do arise from normal operations are:

- 1) Operator error (involving mass limit or material misidentification).*
- 2) Inadvertant accumulation of fissionable material in an obscure place over a long period of time.

*Since water flooding is assumed in setting all limits for the Ceramics Laboratory (due to the presence of fire sprinklers) we do not consider moderation a control. Since physical constraints are required to assure geometry limits, we do not consider operator error a probable source of geometry limit violation since the operator would have to over-ride these physical constraints.

Mass Limit Violations

It is recognized that violation of mass limits can occur from calculational errors when the limit is stated in terms of fissile (^{235}U) weight. This is particularly true when the material handled is UO_2 (not U metal) for which the fissile weight is calculated as:

$$\begin{aligned} \text{Fissile wt.} = & (\text{net wt of } \text{UO}_2) \times \\ & (\% \text{ U in } \text{UO}_2) \times \\ & (\% \text{ } ^{235}\text{U in U}) \end{aligned}$$

Mass limits will be translated into net weight, whenever possible, to obtain an inventory directly verifiable by scale weights without calculation. Violations of mass limits are possible when more than one allowed batch is introduced into the laboratory which is only likely during large-scale projects involving

semi-routine operations.

Under such conditions the personnel who are thoroughly familiarized with the limits are working with continuous inventory postings at each process station. These are maintained for accountability as well as criticality control at the work stations. The work stations are physically separated as a further means of control. (Recall that a batch must exceed twice the allowed mass to even be potentially critical).

Material Misidentification

The controls for material misidentification have already been discussed. If these controls are followed, misidentification of materials could only occur if an operator were ignorant of the coding

system and the enrichment limits presently in force for the laboratory. Fuels Design and Development Section personnel are reminded of the basic coding system at regular training sessions and special meetings are held whenever limits are changed for the laboratory. Qualified fissionable material handlers from other operating groups are permitted to handle fissionable materials in the laboratory but only under the guidance of FD&D personnel.

Inadvertent Accumulations of Fissionable Material

Processing fissionable material from, say, ADU through to finished and ground UO_2 pellets involves some material loss, normally less than about 1%. Much of this material is simply

buried in dry waste, such as gloves, wipes, and dust filters. However, some can accumulate in places, such as the HEPA filters, the pellet grinder exhaust, the press feed system, etc. For compliance with Nuclear Materials Management requirements, effort is made to find inadvertent accumulations of materials whenever "materials unaccounted for" values exceed amounts dependent upon measurement uncertainties. These amounts are small fractions of a minimum critical mass. If inspection of the likely points of accumulation does not result in sufficient material recovery, an effort such as removal of most fissionable material from the laboratory (to reduce radiation background) followed by thorough survey

of the laboratory by radiation detection instruments will be made.

(b) Contingencies Arising from Abnormal Conditions

Fires -- Large fires are not considered likely in the Ceramics Laboratory. Walls, hoods and cabinets are made predominantly of metal. Accumulations of flammable materials are administratively held to a minimum, and waste containers are located in closed metal boxes. Several fire extinguishers are available in the facility, and the 306 Building is located two-three minutes travel time from the 300-Area Fire Station. Small fires due to electrical shorts or equipment overheating are credible; however, no direct criticality contingency is envisioned as a result of such a fire. Such fires would not activate the fire sprinklers (located approximately 30 feet above the floor). The entire 306-W area is zoned "Fire-Fighting Category C," which does allow

water in the form of fog spray. Even if such were used to extinguish a fire in a hood, no criticality potential exists because limits for the laboratory are set with full water flooding of the material assumed.

Flooding -- Criticality potential from flooding must involve some rearrangement of material, since limits for individual units are set with full water flooding assumed. The most readily imagined rearrangement of material is the washing of fissionable material from the hoods from some mechanism that floods them.* General flooding from a pipe break can easily be demonstrated incapable of providing sufficient water depth to flood hoods located three feet from the floor; see for example reference 7 pages 26 and 27. Water from accidentally activated fire sprinklers would accumulate in the hoods; however

*The Zone C categorization is meant to eliminate the possibility of such rearrangement during fire fighting.

the rate of accumulation is conservatively calculated at 0.04 inch per minute, which allows 25 minutes for the line to be valved off before the minimum hood lip depth of one inch is achieved. Since the Fire Department is automatically alerted to a pressure drop in the fire sprinkler line, it is reasonable to assume that the line would be valved off in advance of significant hood flooding.

6.2.3.2 Industrial Hazards

(1) Hydrogen Explosion

Hydrogen is used in the 306-W Ceramic Laboratory as a continuously flowing reducing atmosphere in the processing of nuclear ceramic materials and sintering of nuclear fuel pellets. A relatively large volume of hydrogen is required in these operations to effect the necessary chemical reductions and to sweep volatile impurities out of the furnace chamber. Because of the potential explosion and fire hazards associated with this high

volume usage of hydrogen, the hydrogen gas system, furnaces and associated control equipment are designed for foolproof and fail-safe operation. The entire gas and furnace system is in the routine preventive maintenance system. It is operated only by trained qualified operators, in accordance with a detailed procedure. The design of the system makes the possibility of an accident most unlikely. Specific safety-oriented design features of the system are described in the following paragraphs.

The hydrogen source, a double manifold of cylinders, is located outside the north wall of the 306-W Building between Columns 7 and 8. These cylinders are connected to the manifold by qualified personnel, using sparkproof tools. Each primary connection to a bottle (pigtail) has a check valve to prevent leakage of hydrogen from the manifold. The manifold is equipped with a double pressure reducing station and a pressure relief pop valve, set at 75 psig. This precludes the possibility of high pressure hydrogen

entering the building. Provisions are also available at the manifold to purge the entire piping system with inert gas before hydrogen is introduced. The reduced pressure, normally 30 to 40 psig, is piped outside the building wall to Column 4, where it enters the building. The pipeline crosses Bay 1 of the 306-W Building at the partition of the Ceramics Laboratory and is extended to the furnace location along the south partition. Two separate sources of argon are used in the furnace system. The manual argon purge system is used to purge the furnaces before hydrogen is introduced and to purge the hydrogen from the system at the completion of a process cycle. The safety argon system is another manifold system of cylinders which is on standby, open to the furnace at all times during the use of hydrogen. It is designed to flow automatically in any event of furnace power or hydrogen failure. A part of the furnace start-up procedure includes confirming that a minimum of twice the argon necessary to cool the furnace is

available from this safety argon system. Argon from this system is not used for any other purpose.

Hydrogen cannot be introduced into the furnaces without the availability of the propane pilot flame system to assure burnoff of the hydrogen flowing from the furnace. Propane pressure is required to open a normally closed electric solenoid in the hydrogen line and turn on the large red operation light on the furnace exhaust canopy. A second normally closed solenoid in the hydrogen line is opened only after the propane flame has heated a temperature sensor located at the point of gas exit from the furnace. This valve automatically closes and blocks hydrogen flow and initiates argon flow if the propane flame is extinguished.

The furnace control system, some of which has already been discussed, also includes a pressure switch in the process gas line which will trip, disconnecting power to the furnace if pressure drops to < 15 psig. In this event the solenoid valve blocks the hydrogen from entering the furnace and the safety argon continues to flow at a reduced pressure of 10 psig.

This allows the hydrogen to be purged from the system and protects the furnace with the inert gas until it is cooled. The safety argon system, propane pilot light interlocks and low hydrogen pressure interlocks are checked for operability prior to furnace start-up. This hydrogen gas furnace system has been in routine operation for approximately 20 years, and there has never been any explosion or fire. This experience provides assurance that when the operating procedures are followed occurrence of any mishap is improbable. Any addition to the system, such as the update addition of a new furnace, will include the same or equivalent foolproof and fail-safe design and operating procedures.

(2) Propane Explosion

Propane is supplied to the 306-W Building from a 1000-gallon liquid propane storage tank located about 50 feet east of the 306-E Building. The tank is protected with two pressure relief valves and relief pipes directed away from the 306-E Building. A pressure reducing

valve maintains the propane gas pressure at 15 psig, with relief valves at the tank set at 20 psig. The line runs underground to the 306-E Building, up the east wall inside the building, then west along column line C (Figure 2) into Room 121 of 306-W. There are no propane outlets in the 306-E Building. The propane is used in the heat-treating furnaces in Room 121. A propane line runs north from Room 121 to Column line D, then west to Room 126 of the Ceramics Lab where it is used to burn excess hydrogen from the sintering furnaces (described in detail in preceding section). The pipe runs in the 306-E and 306-W Buildings are located out of reach of the building cranes. All horizontal propane pipe runs in the 306-E and 306-W are next to walls and are at least 11 feet above floor level. The very low gas pressure in these lines and their location in the building makes the risk of pipe rupture extremely low. The propane system was installed in accordance with Hanford Plant Standards for type of pipe, fittings and

pressure test. Completion record
verification of testing is on file at the
Rockwell Engineering Files. Accordingly,
the probability of a propane explosion or
fire in 306-E or 306-W is minimal.

6.3 Specialty Shop

6.3.1 Organization and Administrative Controls

The Materials Department Building Manager, through his resident Facilities Specialist, has the overall responsibility for safe and effective use of the BNW portion of the 306 Building. This responsibility includes integrating the efforts of occupants and involved support groups to provide a safe building which meets all BNW and DOE requirements. Direct in-line responsibility for safety in the 306-W Specialty Machine Shop is assigned to the Specialty Shops' portion of Craft and Operation Services Department. Operations for the facility are supervised by the Specialty Shop's Foreman under the direction of his Section Manager and the Manager of C&OS Dept. The shop foreman is assigned as principal custodian of source and special materials handled. There are generally three or four machinists in the shop, one of whom is designated as shop lead man and assistant (or alternate) in the handling of SS materials.

6.3.2 Description

6.3.2.1 Facility Location and Description

The machine shop area dimensions are approximately 40 feet east and west by 20 feet north and south within 306 Building, adjacent to the south wall, bounded by Column lines A, B and 8, 10. Metal-working equipment includes lathes, honing machine, milling machine, power hacksaw, grinders and drill presses.

6.3.2.2 Process Description

The bulk of fissionable materials handled is depleted uranium with only an occasional machining service performed on thorium or enriched uranium. Ingots, bars, pellets and other similar forms are milled, drilled, turned or otherwise machined to produce finished precision hardware for research and development.

6.3.2.3 Fissile Material

Even though enriched uranium is rarely machined or handled in the Specialty Shop, the facility does maintain the capability and readiness for such service. Special Criticality Safety Specification, to suit the job at hand, govern the operation during times of the material process. Waste Management and Radiation Protection Procedures are in effect at all times.

6.3.3 Hazards

6.3.3.1 Criticality Controls and Contingencies

(1) Fissile Material Description

The shop is limited to uranium-bearing materials only, generally in the form of ingots, bars, pellets, etc.

(2) Criticality Potential

Potential criticality situations are considered to be very remote. (ref.

6.3.3.1 - 4a and b)

(3) Criticality Specifications and Controls

When enriched uranium is handled or machined, the amounts, batch spacing and accountability are governed in strict accordance with approved criticality safety specifications suitable to the enrichment. A significant loss of material during a machining or handling process would be immediately noticed in the accountability and inventory records and would be investigated and resolved.

Standard Maintenance Procedures of C&OS Department require complete cleanout of all surfaces and internal areas of machines including the machine coolant sumps before and after machining operations on enriched uranium.

Internal Criticality Safety Audits of the shop operation are performed monthly if enriched uranium is present. Independent audits are made by Safety and Nuclear Materials Management.

(4) Criticality Contingencies and Safety Analysis

(a) Contingencies Arising from Normal Operations

In normal operations considerations are given to the possibility of improper labeling, spacing error and amount of material.

Proper labeling of enriched uranium is a condition of acceptance of the material to the shop, and the labeling is maintained throughout the machining assignment.

Spacing of batches is understood and maintained by assigned personnel in strict accordance with Criticality Safety Specifications. The amount of material per batch is governed by the limits and controls as described in Part 4.3 of this report.

Mandatory training of personnel prior to assignment to the 306-W machine shop is required in C&OS Standard Maintenance Procedures. Instruction by the foreman is mandatory prior to each assignment for enriched uranium handling or machining. He maintains qualification to instruct others in accordance with BNW Criticality Procedure No. 7.

During the 3-year period prior to this report, enriched uranium machining was performed infrequently to a point that it is considered an unusual operation. Capability and criticality safety provisions are, however, maintained for the present and future.

(b) Contingencies Arising from
Abnormal Conditions

The shop foreman must have prior notice before enriched uranium may be authorized for entry into the shop. The unauthorized entry of material is considered to be an abnormal situation, and subsequent handling of the material could lead to loss of safety control as well as accountability.

Precautionary measures include a sign stating material restrictions at the shop entrance. Shop personnel are informed of the material restriction in the observance of Criticality Safety Procedure No. 7, and Standard Maintenance Procedure No. 10, "General Shop Operations," which limits uranium entry to the shop to depleted uranium except by the custodian's (foreman's) authorization.

6.3.3.2 Industrial Hazards and Safety Analysis

Fire and explosion are considered since uranium metal is pyrophoric and since any small fire has the possibility of leading to a major uncontrolled fire. Fire prevention is based on

strict housekeeping procedures and controls.

These controls include mandatory cleanup of the shop and equipment each working day, plus individual machine cleanups after each use.

Other controls include frequent shop inspections by C&OS management and monthly safety meetings with shop personnel.

Predominant management guidelines supporting control, include BNWL-MA-8, Waste Management; BNWL-MA-43, Safety Guides; and BNWL-MA-6, Radiation Protection Procedures.

6.3.4 Handling of In-Process Material

The Specialty Shop is a machining facility only. Other facilities mentioned in this report, along with safety analysis, may temporarily serve a necessary handling function in the interims of receiving or transferring material intended for machining or recovery. The shop's function is to provide machining with the acceptance of enriched uranium only at the time when provisions are made for the work to begin. The shop-generated waste of enriched uranium (turnings, chips, fines) is transferred as soon as possible, after a machining operation, to a BNW recovery facility or offsite recovery facility, or returned to the customer. During any necessary period prior to transfer, the waste material is maintained in vented containers within the limits described in Part 4.3 of this report. Size of the waste container is kept to

the best practical minimum and is specified in the Criticality Safety Specification to suit the job at hand. The disposal of shop-generated enriched uranium waste is implemented and completed with approvals of BNW Safety and Nuclear Materials Management, and BNW Waste Management, and the approvals confirmed prior to the machining of the material.

6.4 The SNM Storage Area

Efficient use of the laboratories for processing fissionable material requires some fissionable material storage in the building in addition to incidental in-process storage. Examples include 1) feed material for a current pellet fabrication campaign, and 2) material being collected for a shipment. The SNM Storage Area, Room 123, Figure 2, is a locked enclosure on the west end of the building which fills this need. This section deals with the Storage Area.

6.4.1 Organization and Administrative Controls

The Materials Department, through the Building Manager for 306-W has responsibility for the safe operation of the SNM Storage Area. The most important administrative control on the area is its limited access. Manuals and procedures related to SNM accountability require severely limited access to SNM storage, and criticality safety considerations also require limited access. Therefore the Storage Area and the storage arrays within it are locked at all times. These locks are checked at less than four-hour intervals on offshift and holidays by Hanford Security Patrol. The only persons (other than Security Patrol and the Building Manager) having access to the storage area are the custodians and alternates for the two Material Balance Areas (MBAs) represented in the Storage Area.*

*Two sections of the Materials Department routinely store material in the Storage Area -- Fuels Design and Development and Materials Development. MBA custodians have been assigned for each section, each having access to the Storage Area, but each controlling separate storage arrays within the Storage Area.

The general administrative controls listed in Section 5.2 apply to the Storage Area (internal audits, criticality safety specifications, radiation work procedures, etc.). Two additional administrative controls for the Storage Area are the increased training required of the persons having access and the color and size coding of the containers used for fissionable materials.

The custodians and their alternates have access to considerably more fissionable material than those workers limited to the laboratories. The criticality safety specifications for the Storage Area involve geometry restrictions and spacing restrictions not normally encountered in the rest of the building. Therefore custodians and alternates are given special training to keep their knowledge of these restrictions current. Biennial criticality safety testing also reflects these added requirements.

Part of the criticality safety for the Storage Area rests on having limited enrichment ranges in certain storage arrays. Therefore containers are color and size coded for the arrays in which they are permitted, to reduce the possibility of errors in identifying the enrichment. The coding system is part of the required training for MBA custodians.

6.4.2 Facility Description

The general layout of the Storage Area is shown in Figure 4. As indicated, there are three different

types of storage arrays --1) the normal and depleted uranium storage cages (2 cages), 2) the low-enriched uranium storage racks (2 racks), and 3) the high-enriched uranium storage cabinets (2 cabinets). Each of these storage arrays are under separate lock and key, permitting maximum flexibility in sharing the arrays between the two MBAs represented in the Storage Area. Sketches of the low-enriched storage racks and the high enriched storage cabinets are presented in Figures 5 and 6, respectively.

The low enriched storage racks each consist of fifteen 24-foot long, 5-inch ID troughs (heavy gauge steel half-rounds). The troughs' area are spaced 8-inches apart and supported every 24-inches along their length. The troughs may be replaced by shelving under certain conditions, as discussed under "Criticality Controls" below. The racks are approved for U or UO_2 up to 5.1% enrichment.

The high enriched storage cabinets are two types, as shown in Figure 6, differing in color, size of cubicle, and enrichments permitted. The cubicle sizes are designed to limit the number of approved containers per cubicle to three, maximum. Each container is limited to a specific mass that assures the safe storage of material in the cabinet if all the material was at the maximum permitted enrichment. As noted in Figure 6, the

containers going to each cabinet must have lids the same color as the cabinet for which they are intended.

6.4.3 Storage and Shipping/Receiving Procedures

The Storage Area serves as the site for packaging and unpacking fissionable materials shipments. Standard Criticality Safety Specifications for the building require fissionable materials to be handled in minimum safe batches, except when packaged to meet DOT regulations, in which case the criticality safety controls of those regulations apply. Thus individual units or packages inside shipping containers are limited to batch sizes defined by the Criticality Safety Specification for packaging or unpacking the containers. This information is communicated to onsite and offsite receivers of shipments from the 306-W Building. Deviation from this procedure requires special CSSs or temporary deviations, subject to review and approval by CSSA and S&NMM.

Arrays of sealed shipping containers are required to be a minimum of 3 feet from fixed storage arrays. The same is true for packaging/unpackaging operations. Reference to Figure 4 reveals that the Storage Area does have enough floor space to accommodate such operations.

Entry and removal of fissionable material from the storage arrays must be carried out in accordance with CSSs written specifically for each type of array, and entry and removal is only to take place under the direct

supervision of the MBA custodians/alternates. In addition to limits on the type and quantity of fissionable material within the storage arrays, there are limits on the quantity of material entered or removed at one time.

6.4.4 Hazards

Criticality is considered the major credible hazard in the Storage Area. Fire is precluded by the almost total lack of combustible material in the area, and the presence of sprinklers. The storage arrays are built substantially of steel. They rest on a concrete floor and are surrounded by steel walls.

6.4.4.1 Criticality Controls and Contingencies

(1) Fissionable Material Description

The most common form of fissionable material in the Storage Area will be uranium metal and uranium oxide as powder or sintered pellets. Other chemical and physical forms may at times be present, however, subject to review by Nuclear Criticality and S&NMM. All fissionable material will be in sealed metal containers (cans or rods) with the possible exception of large uranium metal pieces stored in the low enriched racks or in the normal and depleted uranium storage cages.

(2) Criticality Potential

Since large quantities of fissionable material are present in the Storage Area, the possibility of a criticality cannot be considered incredible. The following section discusses the controls that will reduce the possibility of criticality.

(3) Criticality Controls

(a) Engineered Safety Features

The two engineered safety features in the current storage arrays are a) the limited width of the troughs in the low-enriched storage rack, and b) the limited size of the cubicles in the high-enriched storage cabinets. The troughs are 5-inch ID half-rounds space 8-inches apart and held coplanar by their supports. They thus form an array which is approximately 5 inches in depth, but with an effective depth of less than 2.5 inches.* The minimum critical slab depth for 5.1% (maximum) enriched uranium is 4.2 inches

*The effective width is calculated by hypothetically allowing the uranium in the troughs to be between the troughs. (Ref. NCS Memo #127 - Brown to Richey, 12-15-72).

fully water reflected and optimally water moderated; but it is 6.3 inches without water reflection. The trough array is considered critically safe for the following reasons:

- a) The effective slab depth is less than 60% of the absolute minimum critical slab depth of optimally water moderated and reflected ≤ 5.1 enriched uranium.
- b) The actual slab depth is less than 80% of the critical unreflected slab depth (still assuming optimal water moderation).
- c) Flooding of the storage racks such as to achieve array reflection is not considered credible.⁽⁷⁾
- d) Holes are drilled every 6 inches in the bottom of the troughs to prevent water accumulation, to minimize

even partial water moderation of the array. Metal cans have a ridge on their circumference that prevents blockage of the holes.

The high-enriched storage cabinets have been analyzed for criticality safety on a different basis than the low-enriched storage racks. Only unmoderated uranium compounds in watertight metal cans are permitted in these cabinets. The size of the cubicles for each type of cabinet physically limits the total number of (approved) containers in each cabinet to 180 maximum. A density analog analysis of the cabinets estimated that this number is less than 0.25 of the minimum critical number of such containers assuming optimum interspersed moderation and full water reflection. The cabinets are fixed greater than three feet apart to preclude significant neutron interaction. They have sloping tops to prevent storage on top and to deflect water away. In addition, the

bottom 18 inches of available storage space has been blanked off to prevent moderation of the material from flooding.

(b) Administrative Controls

The administrative controls for criticality safety have been mentioned previously and will simply be listed here for reference.

- a) Access limited to a few designated and specially trained persons.
- b) Criticality Specifications detailing storage and entry/removal limits for each type of array.
- c) Color and size coding of fissionable material containers to show enrichment range (when any possibility of confusion exists).
- d) Labeling all containers of fissile materials to identify the amount, enrichment and form of the material. Moderated fissile materials are labeled with a distinctive magenta border and the words "moderated material" across the top.
- e) Spacing control on the storage array, emphasized by signs and safe distance indicators (e.g. lines on the floor).

(4) Criticality Contingencies Arising from Abnormal Conditions

Fire -- Storage arrays are constructed entirely of metal with the exception of the Styrofoam spacers in high-enrich-U storage cabinets. Whereas these spacers are important controls for the entry of material, their melting or deformation within the locked cabinets does not constitute a criticality hazard.

Flooding -- Flooding of either storage array such as to produce effective lateral reflection is not credible, as has been shown before. Incidental wetting from fire sprinklers or a water pipe break will not lead to criticality in either array, as mentioned previously.

Earthquake -- Reference 9 concludes the storage arrays per se can withstand credible earthquakes. Measures are taken (e.g. taping down loose rods in the storage troughs) to assure against dislodgement of material from the low-enriched racks. The doors on the high-enriched cabinets keep material from being displaced from them.

6.5 Consequences of Accidents

6.5.1 Nuclear Criticality

Although criticality in the 306-W Building is extremely unlikely it cannot be considered incredible. Accordingly, the probable consequences of a criticality accident are estimated here.

The most severe consequences would, of course, be to employees in the immediate vicinity of the accident. It is assumed that the magnitude of the initial burst would be no more than 2.2×10^{17} fissions. It is further assumed that the accident would be most likely to result from combining water and enriched UO_2 in a nongeometrically-safe configuration and that therefore the reaction could be a pulsating one, alternating between critical and subcritical. The total fissions resulting from all the pulses is postulated to be about 7×10^{18} produced over a 2-hour period. After two hours it is assumed that enough heat is generated to evaporate and splatter the mixture down to a permanently subcritical geometry. The total number of fissions is controlling on the offsite exposures. The basis for these assumptions is Battelle-Northwest Safety Bulletin No. 13, October 21, 1968, Appendix D, Page D-1.

Employees in both 306-W (BNW) and 306-E (HEDL) would be exposed to neutron and gamma radiation in varying degrees of severity, depending upon their initial distance

from the incident, delay and speed of departure, and the amount of intervening shielding material. Most personnel would be protected by 2 to 14 inches of concrete shielding, due to the construction of the building.

A HEDL employee standing inside 306-E directly opposite the UO_2 powder laboratory door would be approximately 100 feet away and would be shielded by 12 inches of concrete. PNL employees in the 306-W Building could be from 16 to 150 feet or more from the incident and shielded with 2 to 14 inches of concrete.

In order to estimate the exposure to employees, the doses associated with a criticality having an initial prompt burst of 5×10^{17} fissions were calculated using the following assumptions:

1. One neutron leaks from the critical assembly per fission.
2. The flux to dose conversion factor for 1 MeV neutrons is 3.225×10^8 neutrons/cm²/rad. ⁽¹⁰⁾
3. The neutron attenuation through ordinary concrete is $e^{-\Sigma_r t}$, where $\Sigma_r = 7.93 \times 10^{-2}$ cm⁻¹ and t = shield thickness in cm. ⁽¹⁰⁾
4. A quality factor of 2 is used to convert from dose to dose equivalent. ⁽¹¹⁾
5. The gamma dose component from solution criticality experiments is $D(\gamma) = \frac{2.5 \times 10^{-14} \text{ rad}}{\text{fission}} \times \frac{\text{no. of fissions}}{r^2}$ where r is the distance from the source to the receptor in meters. ⁽¹²⁾

6. The average energy of the prompt gamma rays is 0.9 MeV. ⁽¹³⁾
7. The attenuation for 1 MeV gamma rays through ordinary concrete is $e^{-\mu t}$, where $\mu/\rho = 0.0637 \text{ cm}^2/\text{g}$, $\rho = 2.3 \text{ g/cm}^3$, and $t =$ shield thickness in cm. ⁽⁵⁾

The following two tables show the estimated doses as a function of distance from the criticality (Table III) and the effect of various thicknesses of concrete on the estimated doses (Table IV).

TABLE III

Estimate of Dose Received from a
Prompt Burst of 5×10^{17} Fissions

Initial Distance from Incident (feet)	D_n (rad)	D_n (rem)	D_γ (rad)	$D_{n+\gamma}$ (rem)
10	1370	2740	1390	4130
15	609	1220	617	1840
20	340	690	350	1040
30	150	300	150	450
50	55	110	56	166
75	23	47	24	71
100	14	28	14	42

TABLE IV

Estimate of Doses Received (rems) from a
Prompt Burst of 5×10^{17} Fissions

Initial Distance from Incident (feet)	Thickness of Concrete Shielding (in)							
	0	2	4	6	8	10	12	14
10	4130	2500	1560	990	640	410	270	180
15	1840	1100	700	440	280	180	120	80
20	1040	630	390	250	160	100	70	45
30	450	270	170	110	70	45	30	20
50	166	100	63	40	26	17		
75	71	43	27	17				
100	42	26						

The offsite exposures were estimated according to the following criteria:

1. The inventory of fission products generated during the criticality were calculated using the computer program RIBD.^(4,5) During the first day after the criticality event, the concentration of each nuclide may change due to radioactive decay and buildup; i.e. increasing in some cases and decreasing in others. The release inventory was based on the maximum concentration occurring within the first day regardless of when the maximum occurred. (The maximum for most nuclides occurs within one hour). The release inventory for 7×10^{18} fissions is given in Table V.
2. All noble gases and 25% of the halogens were assumed to be released. All other nuclides (nonvolatile) were assumed to be retained within the building since all effluent gases pass through a HEPA filter prior to release to atmosphere.
3. Potential doses to an individual located 1900 meters downwind from the gas release were calculated using atmospheric dispersion estimates based on the Hanford dispersion model for moderately stable conditions for a short release period.

TABLE V

Criticality Release Inventory

<u>Nuclide</u>	<u>Total Ci Released</u>
^{83m}Kr	2.61×10^1
^{85m}Kr	1.13×10^2
^{85}Kr	1.08×10^{-3}
^{87}Kr	7.0×10^2
^{88}Kr	4.55×10^2
^{89}Kr	2.89×10^4
^{90}Kr	1.09×10^5
^{91}Kr	4.57×10^5
^{131}I	1.28×10^0
^{132}I	4.69×10^0
^{133}I	2.45×10^1
^{134}I	3.36×10^2
^{135}I	8.54×10^1
^{131m}Xe	2.67×10^{-3}
^{133m}Xe	3.85×10^{-1}
^{133}Xe	9.10×10^0
^{135m}Xe	7.70×10^0
^{135}Xe	1.11×10^2
^{137}Xe	2.66×10^4
^{138}Xe	8.40×10^3
^{139}Xe	9.66×10^4
^{140}Xe	2.98×10^5

4. Inhalation doses were calculated using the computer program DACRIN.⁽²⁾ External doses were calculated using the computer program SUBDOSA.⁽³⁾ Finite plume dimensions were considered when calculating the gamma contribution to total body dose.
5. Population doses were calculated using models and data as described in WASH-1538 (Hanford Environmental Impact Statement). The population within a 50-mile radius of the 300 Area was interpolated from population projections made in WASH-1538. Results of the criticality dose calculations are shown in Table VI:

TABLE VI
Doses from Criticality

External Exposure				
Organ of Interest	Maximum Individual Dose (rem)		Population Dose (person-rem)	
	1-year	50-year commitment	1977	1985
Total Body	1.7E-1		3.0E + 0	3.2E + 0

Inhalation Pathway				
Organ of Interest	Maximum Individual Dose (rem)		Population Dose (person-rem)	
	1-year	50-year commitment	1977	1985
Total Body	1.2E-2	1.3E-2	4.7E-1	4.9E-1
Bone	8.7E-2	9.1E-2	3.3E+0	3.5E+0
Lung	1.2E-1	1.2E-1	5.1E+0	5.3E+0
Thyroid	1.4E+0	1.4E+0	4.9E+1	5.3E+1
GI(LLI)	3.4E-2	3.4E-2	1.3E+0	1.4E+0

For comparison, Nuclear Regulatory Guide Chapter 1, Section 100-11 allows the use of 25 rems to the whole body and 300 rems to the thyroid for establishing power-reactor exclusion zone boundaries. Inhalation doses to total body, bone and thyroid were calculated assuming inhaled material was in a soluble form (Class D) and for lung and GI-tract dose the material was assumed to be only slightly soluble (Class W). Thyroid doses via the milk path were neglected because of the limited dairy industry located within a 50-mile radius of the 300 Area. If necessary it would be feasible to confiscate the milk in the affected area for the required time.

Nonvolatile fission products were found to be negligible because all effluent gases pass through a HEPA filter before release to the atmosphere.

6.5.2 Explosions

Although a hydrogen explosion in the 306-W Building is unlikely, it cannot be considered incredible. Accordingly, the probable consequences of an explosion are estimated using the following assumptions:

1. The most likely place for an explosion to occur would be in the hydrogen sintering furnaces located in the Ceramic Laboratory.

2. The charge in the furnace at the time of the explosion consists of 17.7 kg of UO_2 with the isotopic content shown below:

TYPICAL ISOTOPIC CONTENT OF
 UO_2 CHARGE IN SINTERING FURNACE

<u>Nuclide</u>	<u>Wt%</u>	<u>Ci</u>
^{234}U	0.026	4.92×10^{-3}
^{235}U	5.1	6.07×10^{-4}
^{236}U	0.062	1.70×10^{-3}
^{238}U	94.8	2.51×10^{-2}

3. The UO_2 consists of 1 μm micron-sized particles.
4. As a result of the explosion, the 306-W Building is breached resulting in the release of the entire 17.7 kg of UO_2 at the roof of the 306-W Building.

These assumptions are extremely conservative since 1) it is unlikely that the 306-W structure would be breached as a result of the explosion, 2) in the event of breaching, not all of the 17.7 kg would escape the building, and 3) the UO_2 particles would be much larger than 1 μ size and therefore would not be as widely dispersed.

The offsite exposures were estimated according to the following criteria:

1. Potential doses to an individual located 1900 meters downwind beneath the center of the release were calculated using

atmospheric dispersion estimates based on USNRC Regulatory Guide 1.3.

2. Inhalation doses were calculated using the computer program DACRIN.⁽²⁾ External doses were calculated using the computer program SUBDOSA.⁽³⁾ Finite plume dimensions were considered when calculating the gamma contribution to total body dose.
3. Inhalation doses to total body and bone were calculated assuming inhaled material was in a slightly soluble form (Class W) and for lung and GI-tract dose the material was assumed to be insoluble (Class Y).
4. Population doses were calculated using models and data as described in WASH-1538 (Hanford Environmental Impact Statement). The population data within a 50-mile radius of the 300 Area was interpolated to estimate the population doses for the years 1977 and 1985.

A complete set of dose calculations for the postulated explosion is shown in Table VII. External exposure is not a significant pathway for this accident. Inhalation doses to total body and bone were calculated assuming

inhaled material was in a slightly soluble form (Class W) and for lung and GI-tract dose the material was assumed to be insoluble (Class Y).

TABLE VII
Doses from Furnace Explosion

Organ of Interest	Maximum Individual Dose (rem)		Population Dose (person-rem)	
	1-yr dose	50-yr commitment	1977	1985
Total Body	1.2E-3	1.4E-3	5.0E-2	5.2E-2
Bone	1.2E-2	2.3E-2	8.3E-1	8.6E-1
Lung	4.1E-1	1.1E+0	3.9E+1	4.1E+1
GI(LLI)	8.8E-5	9.5E-5	3.3E-3	3.6E-3

6.5.3 Fire

Although the occurrence of a uranium metal fire severe enough to breach the integrity of the 306-W Building is extremely unlikely its consequences should be examined.

Tests have been conducted by several investigators to estimate the extent of plutonium release from burning metal during exposure of plutonium and its compounds to high temperatures and fires.⁽⁶⁾ It was found that for plutonium fires a 0.05% release of plutonium in aerosol form is a good assumption.⁽⁶⁾

It was assumed for this analysis that uranium metal fires also release 0.05% of the burning metal in aerosol form. Using a conversion of 0.05% of the uranium in a metal fire to aerosol form suitable for dispersion by air and assuming that the 306-W Building is breached, it is possible to calculate the amount of uranium necessary

to burn to equal the radiological release equivalent to that calculated in Section 6.5.2 (explosion in a hydrogen sintering furnace). In that analysis 17.7 kg of UO_2 of typical isotopic content shown in Table I was released at 306-W Building. This corresponds to 15.6 kg of uranium metal (assuming 88% metal in the oxide). In order for 15.6 kg to be released from a fire over 30,000 kg of uranium would have to ignite. This represents about three times the maximum theoretical limit and about six times the practical limit of the SNM storage facility in the 306-W Building. It is therefore concluded that a release of radioisotopes to the environment from any postulated uranium fire would be less than that calculated for the explosion in the hydrogen furnace (Paragraph 6.5.2).

6.5.4 Accidental Releases - Thorium Oxide Fuel Development Laboratories

Three accidents were postulated for the TOFDL that led to the accidental release of radioactive materials to the environment: 1) a design basis explosion, 2) a flammable gas explosion, and 3) a design basis fire. Accident scenarios were developed for these accidents in the TOFDL and resultant doses were calculated. The criteria and assumption used in calculating doses and environmental releases for the TOFDL are given in the Appendix, "Environmental Impact Assessment for the Thorium Oxide Fuel Development Laboratory." (15)

In the first scenario, an explosive gas was postulated to originate from a leaking 60 ft³ hydrogen bottle, which was used in the TOFDL process area for welding and brazing operations. After dilution with room air, the explosive mixture came into contact with an ignition source. The resulting explosion was assumed to occur with sufficient force and in the proper location to breach the primary containment system.

Under such conditions a maximum of 90 grams of radioactive thorium and uranium powders challenged the final bank of HEPA filters with 0.22 milligram transmitted to the environment.

As shown in Table VIII the resultant first year doses to the maximum individual from this accident were projected to be 6.2×10^{-5} mrem/yr to the lung. The dose commitment to the maximum individual was 1.4×10^{-3} mrem to the bone.

TABLE VIII

Calculated Doses Received by the Maximum Individual from the Worst Case TOFDL Accident (a Design Basis Explosion or Flammable Gas Explosion)

	<u>Total Body</u>	<u>Bone</u>	<u>Liver</u>	<u>Lung</u>
First Year (mrem/yr)	1.0×10^{-7}	2.9×10^{-6}	1.7×10^{-7}	6.2×10^{-5}
Dose Commitment (mrem)	3.9×10^{-5}	1.4×10^{-3}	8.0×10^{-5}	3.8×10^{-4}

The second accident considered for the TOFDL was a flammable gas explosion in the exhaust system. Maintenance welding operations could involve the use of hydrogen at the work location. It was assumed that all the gas from

one hydrogen bottle escapes into the process building and was drawn into the room air exhaust system. When this gas reached the final HEPA filters, it was mixed with air and thus was assumed to contain an explosive mixture. With an ignition source, the mixture could explode with enough force (greater than 80 psi) to breach the final two stages of HEPA filtration.

The maximum expected radionuclide inventory on the final HEPA filters was calculated using the following conservative data and assumptions. The exhaust from the fuel process area will approximate 2800 ft^3 per minute. With the conservative assumption of an average radionuclide concentration in this exhaust of 1/10 of the occupational Maximum Permissible Concentration for insoluble radium-226 in air, $5 \times 10^{-12} \text{ } \mu\text{Ci/cc}^3$.⁽¹⁵⁾ and a 5-year collection time, the total inventory on the HEPA filters would be about 0.22 mg. It was conservatively assumed that the total radionuclide inventory of these filters would be released to the environs. Since the release is identical to the Design Basis Explosion, the resultant doses will be identical (see Table VIII).

The third accident considered was a design basis fire. In that scenerio, the fire was postulated to last two hours. Although the combustible material was assumed to burn at a linear rate over this period, in reality the burning rate would vary during the course of the fire and the quantity of material consumed and the amount of energy released would be less than calculated due to the lack of oxygen and the loss of heat to sprinkler systems and other large heat sinks.

Radioactive particles could be made airborne by the actions of a fire. Under the conditions postulated, soot plugged fume hood HEPA filters thereby restricting flow. It was conservatively assumed that all the radioactivity from this source was made airborne during the course of the fire. The final source term released to the environs was 0.19 mg which is less than that postulated from the other accidents.

6.5.5 Maximum Credible Accident

Based on the analysis it is concluded that the maximum credible accident in the 306-W Building that would cause release of radionuclides to the environment would be a criticality. Using the assumptions discussed in Section 6.5.1, the dosages shown in Table VI, Section 6.5.1 are calculated.

6.6 Interaction with the 306-E Building

6.6.1 Criticality

If nuclear criticality were to occur in the 306-W Building near the common wall with the 306-E Building, the consequences to personnel in 306-E would be essentially the same as those to PNL personnel from a criticality accident in 306-W, which are described in Section 6.5.1 of this report.

6.6.2 Fire and Explosion

There is small likelihood that a fire or explosion in 306-W will have significant impact on the 306-E portion of the building. A 12-inch thick firewall between the two sides of the building (with its two steel doors that are sealed closed) provides substantial protection to either side of the building from fire or explosion in the other.

The two fire suppression sprinkler systems (one in each side of the building) are completely independent of each other.

6.6.3 Services

Electrical -- The normal electrical power supplied to the two halves of the 306 Building are separate, connected only by a normally open breaker. If normal power is interrupted in either side, the other transformer can supply the entire building through this breaker. The 30-kVA emergency power system is common to the whole 306 Building.

Alarms -- The 306-E and 306-W fire alarms are completely separate from each other. The evacuation alarm system is common to the building. The criticality alarm system is on emergency power and is also common to the building, and its control panel is located in 306-W.

Sewers -- The only two sewer systems are for sanitary and process wastes. The process sewers in 306-W feed into the sewer main of the building at three points. The main runs north-south in the 306-E Building about ten feet from the west wall, and the process wastes leave the building at the south side. The feeder sewers are 4-inches in diameter and the main is 6-inches in diameter, which makes plugging of the main unlikely. Plugging of the feeder lines has occurred in both 306-E and 306-W, but it has never occurred in the main. Plugging of the main downstream of the 306-W connection could back up fluid from either side of the building into the other, but not to an extent that would constitute

a criticality contingency. This same conclusion applied to the sanitary sewer system. The principal fluid flow in the process sewer from 306-W is neutral cooling water, but at times there are acids, caustics, metal cleaning solutions and rarely low-level natural or depleted uranium wastes. No combustible liquids are routinely drained into the process water, and they would get into this system only in the event of an accidental spill. Acidic and caustic wastes from 306-E are neutralized before being pumped into the process sewer.

Ventilation -- The 306-E and 306-W ventilation systems are completely independent of each other. All systems in 306-E are positive in pressure with respect to 306-W. Toxic vapors in more than negligible amounts are present only in the chemical cleaning bay, where they are carefully controlled by engineered safety equipment. All vapors from the cleaning tanks are exhausted directly to the atmosphere through a filter and a scrubber. The pressure in the chemical cleaning bay is negative with respect to the rest of the 306-E Building. Accordingly, ventilation interaction is negligible.

Water Supply -- Sanitary and process water supplied to 306-E and 306-W are independent of each other, each being supplied through a 6-inch feedline from a larger 300-Area main. A rupture of the water supply in either

side of the building would not affect the pressure in the other side because the automatic pump controls in the powerhouse would restore the mainline pressure. A negligible amount of water could leak around the sealed equipment door in the firewall from the flooded site.

REFERENCES

1. Paglieri, J.N. "300-Area Site Description," HEDL-TME 75-13, Feb. 1975.
2. Houston, J.R.; Strenge, D.L. and Watson, E.C.; DACRIN - A Computer Program for Calculating Organ Dose from Acute or Chronic Radionuclide Inhalation, BNWL-B-389, Battelle, Pacific Northwest Laboratories, Richland, WA, 1974 (reissued 1975).
3. Strenge, D.L.; Watson, E.C. and Houston, J.R.; SUBDOSIA - A Computer Program for Calculating Individual External Doses from Accidental Atmospheric Releases of Radionuclides, BNWL-B-351, Battelle, Pacific Northwest Laboratories, Richland, WA, 1975.
4. Gumprecht, R.O., Mathematical Basis of Computer Code RIBD, DUN-4136, Douglas United Nuclear, Inc., Richland, WA, 1968.
5. Gumprecht, R.O., Computer Code RIBD, DUN-SA-69, Douglas United Nuclear, Inc., Richland, WA, 1969.
6. Powers, C.S., Safety Analysis Report - 231-Z Building, BNWL-CC-1924, Battelle-Northwest, Richland, WA, March 1969.
7. Anthis, R.M.; Bowersock, R.V.; Illg, R.N.; and Studer, R.R.; Safety Analysis Report 306 Building, BNWL-CC-2001, Battelle-Northwest, Richland, WA, March 14, 1969.
8. Occurrence Report - "Unexpected Release of Uranyl Nitrate Solution," 76-BNW-14.
9. Letter - C.R. Richey to H.V. Larson, April 11, 1977, "Consideration of Natural Force Loading in the Storage of Fissionable Materials."
10. J.N. Paglieri, "Criticality Detector Coverage at HEDL," TC-244, April 1975.
11. American National Standard - Dosimetry for Criticality Accidents, ANSI N13.3 - 1969.
12. "Nuclear Criticality Safety," TID - 26286, National Technical Information Service, Springfield, VA, 1974.
13. Reactor Handbook - Volume III, Part A, Physics, Interscience, New York, 1962.
14. "Radiological Health Handbook," Bureau of Radiological Health, US DHEW, Rockville, MD, January 1970.
15. "Environmental Impact Assessment for the Thorium Oxide Fuel Development Laboratory," Pacific Northwest Laboratory, July 1978.
16. US Department of Energy Administration Manual Chapter 0524, "Standards for Radiation Protection," Washington, DC 20555, April 8, 1975.

- △ AIR SAMPLE STATIONS
- PASSIVE NEUTRON DETECTOR
- CRITICALITY DETECTOR

FIGURE 2. Simplified Floor Plan of 306-W Building.

FIGURE 4.
LAYOUT OF THE SNM STORAGE AREA

NOTES:

- 1 NORMAL AND DEPLETED U STORAGE CAGES
- 2 LOW ENRICHED STORAGE RACKS
- 3 HIGH ENRICHED STORAGE CABINETS

FIGURE 5. Elevation of Low-Enriched Storage Racks

Face-On View (Scale: $1/8'' = 1'$)

Cross-Section (Scale: $1/2'' = 1'$)

Figure 6. Elevation of High-Enriched Storage Cabinets

Red Cabinet Notes

Max. Enrichment - 30%
Can Size: 4 1/2" x 5 1/2"
Grams U-235
Per Can: 450 max.
Cans per Cubicle: 3 max.

Blue Cabinet Notes

Max. Enrichment - 100%
Can Size: 3 1/2" x 3 1/2"
Grams U-235
Per Can: 370 max.
Cans Per Cubicle: 3 max.

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